

Water Security in the UAE: Challenges and Opportunities

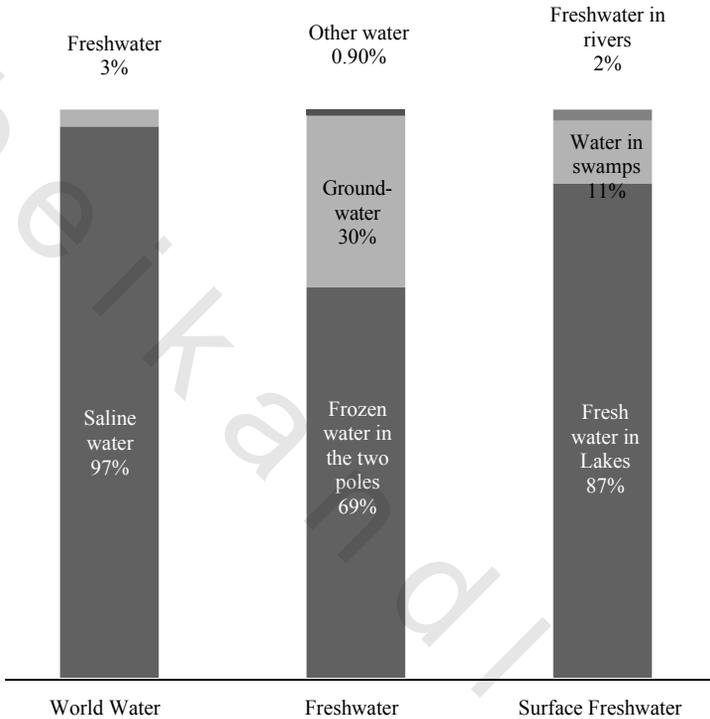
Mohammed Dawoud

Scarcity of renewable water resources is a global challenge facing many countries, especially those located in the world's arid and hyper-arid zones. Statistics indicate that global water resources total around 1,386 billion cubic meters (bcm). Freshwater constitutes just a small percentage of this (around three percent), while the overwhelming proportion is salt water in the seas and oceans. Sixty-nine percent of that fresh water is in ice form, which only leaves 31 percent of the total fresh water that is readily accessible. Of this, 30 percent is non-renewable groundwater and only two percent is renewable, as shown in Figure 9.1. Thus, more than one billion inhabitants in developing countries suffer from a lack of drinking water and sanitation.¹

Water resource preservation has therefore become one of the world's major contemporary challenges, particularly in arid countries like the United Arab Emirates and the other GCC states. Studies indicate that the GCC states are experiencing a water deficit that reached 15 bcm in 2008, a figure which is expected to increase to 35 bcm by 2030.² Hence, since the establishment of the federation in 1971, the UAE government has not only realized the importance of water and its role in economic, agricultural and demographic development, but also invested in the water sector, resulting in the establishment of the necessary infrastructure to develop these resources sustainably, including wells, dams to store rainwater, desalination plants, distribution networks and wastewater treatment plants. This required substantial capital investment, as well as significant operational costs that were borne by the state.

Figure 9.1

Global Water Balance and Fresh Water Available for Use



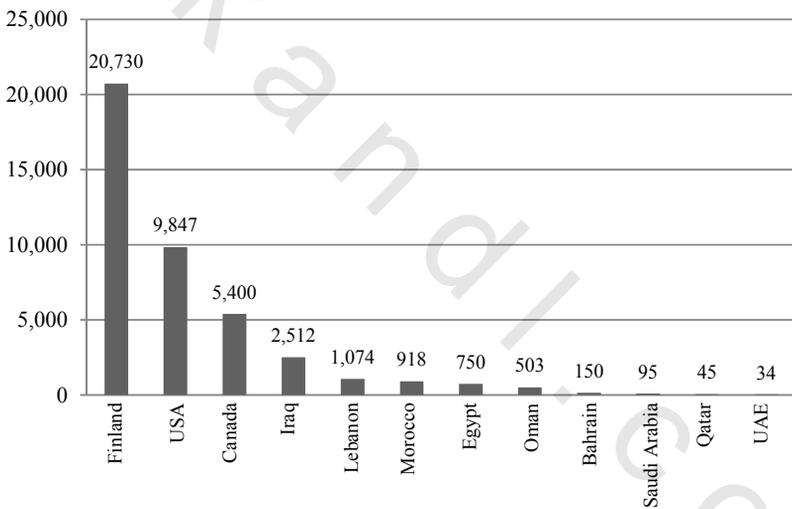
Source: UNESCO, *Water for People, Water for Life*, United Nations World Water Development Report, 2003 (Paris: UNESCO Publishing, 2003).

The UAE is located within an arid zone and has scant renewable water resources owing to poor rainfall and the absence of permanent flowing surface water sources such as rivers, freshwater lakes or flowing valleys. Total renewable water from natural sources in the UAE is estimated at 33 cubic meters per capita per year, according to a World Bank regional report on development in the Middle East and North Africa in 2007³—a low quantity by international standards as shown in Figure 9.2.

The UAE falls well below the water poverty line (1,000 cubic meters per capita per year), although some researchers believe that, in arid zones, renewable water resources from non-natural sources such as desalinated water or treated wastewater, should be included. Nonetheless, this would only raise the figure to 320 cubic meters per capita per year. This lack of renewable water presents a host of challenges for the government, which must provide the fresh water needed for rapid economic and social development, whilst at the same time ensuring environmental protection, public health and food security.

Figure 9.2

Comparative Renewable Water Resources from Natural Sources in the UAE (m³ per Capita per Year)



Source: UNDP, *Human Development Report 2006* (New York: UN, 2006).

Conventional Water Resources in the UAE

Surface Water (Rain, *Wadis* and Dams)

When rain falls over the UAE, especially in mountainous areas, some of the rain water accumulates on the surface, after which it begins moving down the slopes through minute channels, quickly accumulating in larger

channels or *wadis* that snake towards main drainage basins. The *wadis* are dry river beds which contain water only during heavy rainfall when there is surface runoff. When water does flow into them it can cause flash floods, particularly following short rain storms in mountainous areas of the northern and eastern parts of the UAE.

Measurements carried out by the UAE Ministry of Agriculture and Fisheries in 1993, and the Ministry of Environment and Water in 2005, show that the Western Region of Abu Dhabi is characterized by severe drought and an absence of floods. This is due to the scarcity of annual rainfall (40 millimeters), a high rate of evaporation (3,360 millimeters per year), an absence of vegetation and the highly permeable and porous sand dunes that cover most of the surface of the area. In the north, topographical maps and aerial and satellite images show 70 dry drainage basins in the northern Al-Hajar mountain range and the Musandam Peninsula, including 58 basins within the UAE. These valley basins range in size between five square kilometers (like Fujairah's Wadi Dhadnah) and 475 square kilometers (such as Wadi Bih in Ras Al-Khaimah). Some large valley basins witness more than one flash flood per year, while others may not experience flooding for many years. The annual flood water contribution to water resources of the UAE, as estimated by the Ministry of Environment and Water in 2009, ranges from 23 to 138 million cubic meters [mcm] (see Table 9.1). These quantities of water are not insignificant, and contribute to replenishing groundwater and improving its quality.

Some *wadis* run across the border between Oman and the UAE, passing through a dozen catchment areas, and the average total annual flow of these *wadis* is approximately 7.6 mcm per year. Sometimes the trans-border flow is huge and may lead to damaging floods. The estimated replenishment of groundwater aquifers is about 30.9 mcm per year. Usually, rainfall occurs in the months of January, February and March, and there is a cycle of above average rainstorm frequency, every 3–4 years.

Studies have shown that the lowest rates of rainfall to cause runoff was 75 millimeters per year on the mountains of Oman and 90 millimeters per year on Jebel Hafeet in Al-Ain, UAE, during the period 1981–1992.⁴

Table 9.1
Estimates of Surface Runoff in the UAE

Name of Water Basin	Area (km ²)	Average Annual Rainfall (mm)	Surface Runoff, million cubic meters (mcm)	
			3% Rate of Rainfall	18% Rate of Rainfall
Mai	61	130	0.24	1.42
Ghalilah	76	136	0.31	1.86
Mada	95	130	0.37	2.22
Zikt	100	148	0.44	2.66
Naqab	107	137	0.44	2.63
Al-Wurayah	137	145	0.60	3.58
Hatta	164	145	0.71	4.28
Wahala	195	121	0.71	4.25
Al-Makassar	214	140	0.90	5.39
Ham	291	140	1.22	7.33
Al-Qor	340	150	1.53	9.18
Al-Bih	476	121	1.72	10.35
Al-Toyen	503	133	2.01	12.04
Lamha	1,236	125	4.64	27.81
Qada'a	1,362	120	4.90	29.42
Other basins in the UAE			2.26	13.59
Total basins in the UAE			23	138

Source: UAE Ministry of Environment and Water, "United Arab Emirates Water Conservation Strategy," UAE, 2010.

However, a significant rain storm (e.g., 30 millimeters) would be more than enough to create surface runoff in any *wadi* catchment area. The results of studies carried out on the UAE's *wadis* illustrate that the highest risk of flooding occurs in the Shik, Sidr and Al-Ain Al-Fayda *wadis*, and that the lowest risk of flooding is in Al-Khokeirah and Al-Mreikhah. The average annual depth of surface runoff during the study period ranged between five and twenty millimeters, and the proportion of the rain that formed this runoff was, on average, seven percent—between three percent (*wadi* Jebel Hafeet) and eighteen percent (the *wadis* of the Omani Hajar).⁵

Projects to construct dams at the exits of the *wadis* in order to capture and store surface runoff in the *wadis* have attracted great attention in the UAE recently due to their potential importance to groundwater replenishment, compensation for limited supply, and prevention of rainwater loss. These projects capture rain and flood water falling on the mountains and highlands that would otherwise flow quickly towards the low-lying areas and the coast, destroying farms and washing away the surface layer of agricultural soil, leading to a deterioration in soil fertility.

The UAE government has already constructed several dams, the most important of which: Al-Shuwaib Dam in Al-Ain City, Rashid Dam on the outskirts of Hatta, in addition to five other large dams at Wadi Ham, Wadi Bih, Wadi Izin, Wadi Gema and Wadi Al-Ghail. Also, 23 other locations were selected for study and the construction of dams: Wadi Qada'ah, Wadi Al-Qor, Al-Fara', Wadi Hefna, Wadi Al-Toyen, Wadi Wahla, Wadi Safta, Wadi Al-Wurayah, Wadi Al-Baseer, and Wadi Al-Naqab (Al-Hbous), Wadi Siji, Wadi Zikt, Wadi Al-Mawrid, Wadi Ghalilah, Wadi Al-Ferfar, Wadi Al-Motarid, Wadi Shawkah, Wadi Ashwani (Kadar), Wadi Hazf, Wadi Shaam, Wadi Ramth, Wadi Safad (Al-Qariyah) and Wadi Shaba. The storage capacity of the catchment dam depends on many factors, most importantly the drainage basin area—the more drainage basin area the more dam's ability to store water. Water harvesting rates by dams is attributed in the first place to rainfalls—the volume of the water harvest rises with the increased rainfall.

The Ministry of Environment and Water cares for dams and their maintenance. A big number of dams were built to store large quantities of rainwater. The specialized department of the late Sheikh Zayed bin Sultan Al Nahyan has constructed about 57 dams and a water barrier in the Northern Emirates in three phases consisting of 28, 27, and 2 dams. The total number of dams in the state is about 114 dams, with storage capacity estimated at 118 mcm. Moreover, in terms of infrastructure development, the UAE intends to construct about 70 new dams in the eastern and northern regions, with the aim of enhancing groundwater storage and building an integrated system of infrastructure for the development of water resources in the country to counter environmental and water challenges. The dam projects aim to achieve the following objectives:⁶

- Replenishing aquifers with the surface runoff.
- Raising groundwater levels and improving its quality.
- Stopping the inland intrusion of the seawater, and reducing the impact of seawater pollution of coastal aquifers.
- Providing a source of surface water for agriculture and drinking and for the purpose of development.
- Providing protection against floods and minimizing their impacts.
- Maintaining agricultural soil and preventing flood-related erosion.
- Using sediment accumulated behind dams to improve agricultural soil.
- Serving the environmental, climate and tourism.

The levels of groundwater replenished by dam sites are monitored through observation wells used by the Ministry of Environment and Water to monitor levels in different areas. Observation wells contribute to determining groundwater levels and readings are taken monthly, using electronic devices, and stored in the Ministry's database. This enables the efficient and rapid collection of accurate information.

Since their construction, the dams have played a significant role in reducing the risks of flash floods and protecting homes, roads and farms. Their beneficial role in feeding groundwater is clear from the low concentration of total dissolved salts in groundwater, as well as the high water levels in observation wells established specifically for this purpose. It is also clear from radioactive isotope studies analyzing samples of water from the dam sites.⁷

The total storage capacity of the dams in the UAE is about 118 mcm. The results and data of the studies carried out by the UAE Ministry of Environment and Water point out that the largest nine dams in the state stored about 178 mcm of water in the period 1982–2000. This amount increased to about 211 mcm in 2007, as shown in Table 9.2.⁸ Constructing and maintaining dams involves high capital investment costs, which are met by the state as a result of the UAE government's belief in the importance of such projects. Table 9.3 illustrates the magnitude of government investment in the construction of dams in the period 2001–2004.

Table 9.2
Dams in the UAE

Dam	Location	Dam Type	Date built	Height (m)	Length (m)	Lake Capacity (m ³)	Stored Water until 2007 (m ³)	Area Benefited
Ham	Fujairah	Cumulus	1982	16	2800	7,700,000	27,500,000	Fujairah/Kalbah
Al-Bih	Ras Al-Khaimah	Cumulus	1982	18	220	7,500,000	44,567,000	Al-Breirat/Al-Nakheel
Gulfa	Ajman	Concrete	1984	8	235	250,000	4,505,000	Mzeirea/Masfout
Izin	Ras Al-Khaimah	Cumulus	1982	10	110	500,000	9,713,000	Izin/Al-Hamraniyah
Al-Ghail	Ras Al-Khaimah	Concrete	1982	4.5	26	15,000	206,200	Al-Ghail
Hazf	Ajman	Cumulus	1991	11	850	3,000,000	7,660	Mzeirea/Masfout
Al-Owais	Fujairah	Cumulus	1991	18	230	3,500,000	17,000	Dhadnah
Al-Toyen	Fujairah	Cumulus	1992	23.5	342	18,500,000	34,750	Al-Toyen & Al-Hamraniyah
Al-Wurayah	Fujairah	Cumulus	1997	33	367	5,200,000	900	Al-Bidiyah/Khor Fakkan
Al-Basirah	Fujairah	Cumulus	1999	8	885	1,600,000	3,450,000	Diba

Source: Mohammed A. Dawoud, *Water Sources and their Importance in the UAE* (Abu Dhabi: Sultan Bin Zayed's Culture and Media Centre, 2011).

Table 9.3
Capital Cost for the Construction of Dams in the UAE (2001–2004)

Year	Dam Set	No. of Dams	Storage Capacity (mcm)	Cost	
				AED Million	\$ Million
2001	Zayed, phase 1	27	5.9	210	57
2002	Zayed, phase 2	28	7.1	320	87
2003	Zayed, phase 3	2	0.4	28	7.6
2004	Zayed, phase 4	1	0.1	6	1.6
Total				564	153.2
Average storage cost per cubic meter of rainwater				42	11

Source: Ministry of Environment and Water, op. cit.

The Ministry of Environment and Water is currently planning to build a further 68 new dams to collect flood water, bringing the number of total dams in the state to 182. This program will contribute to increasing the availability of fresh surface water supplies and the rates of aquifer replenishment, improving their quality and reducing the deterioration of their resources. Investment costs for the construction of these dams are expected to be roughly AED228 million, as estimated by the Ministry and illustrated in Table 9.4.

Table 9.4
Projected Capital Costs for the Construction of New Dams

Year	Dam Type	No. of Dams	Storage Capacity (mcm)	Cost	
				AED Million	\$ Million
2012–2013	Concrete	15	0.31	51	14
2012–2013	Cumulus	36	2.28	163	44
2012–2013	Rock	3	0.21	14	4
Total				228	61

Source: Ministry of Environment and Water, op. cit.

Groundwater

Groundwater is the main source of – and the only natural – water used in the UAE, despite the over-exploitation of some aquifers, and the degradation of their water quality. There are many aquifers in the UAE; both shallow and deep.

Shallow Aquifers

Shallow aquifers are the most common in terms of productivity. They consist of newly formed sand, sediments and sandstones eroded as a result of the wind and other factors (weathering) occurring in different eras, but most notably the (present) Quaternary period. Water-bearing layers constituting shallow aquifers in the Emirate of Abu Dhabi include: Quaternary aquifers directly underlain by the Lower Fars formation; Quaternary sands and gravel directly underlain by Upper Fars formations; coastal and inland marshes (*sabkhas*); and Quaternary sand and gravel directly underlain by both Lower and Upper Fars formations (Jebel Hafeet area). In the Northern Emirates there are a number of other

water-bearing formations constituting shallow aquifers, including: sandstone aquifers; natural cumulus aquifers; coastal and inland *sabkhas*; and alluvial aquifers.

Deep Aquifers

Deep aquifers consist of cracked limestone bedrocks, volcanic rocks (ophiolitic) and carbonate rocks. The carbonate rock layers are formed at great depths. They have been neither widely discovered nor exploited. Among the most important deep aquifers in the UAE are: the Al-Juwaiza aquifer, a volcanic rock aquifer (ophiolitic), and cracked limestone bedrocks all in the northern emirates; limestone bedrocks to the south of Al-Ain City and the Simsima aquifer, both in Abu Dhabi; and a cracked alluvial aquifer in Fujairah.

The productivity, volume and quality of groundwater from an aquifer depends on its location, the depth of its water-bearing formations, the various characteristics of each aquifer and the size of the aquifer, as shown in Table 9.5.⁹ These aquifers are divided into two types according to their replenishment rates.

First are non-renewable aquifers, replenished over the course of thousands of years. This water accumulated during the formation of rock layers in previous ages. Geological studies indicate that there are important events that replenished these aquifers—between 32000 and 26000 BC as well as in the period between 9000 and 6000 BC.

Second are renewable aquifers recharged by dams and rainfall in *wadis*. Some studies conducted by the Ministry of Environment and Water and the Environment Agency—Abu Dhabi estimate that these aquifers' annual recharge rates range between 140 and 190 mcm of water annually.¹⁰

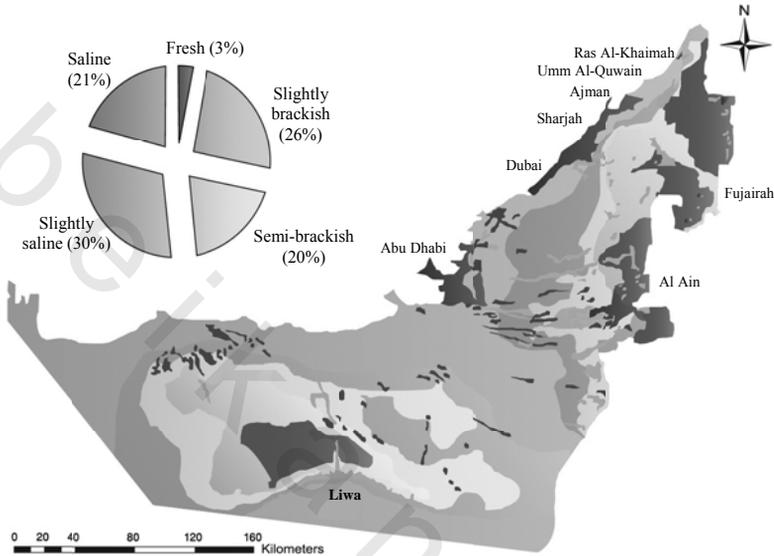
There are large amounts of groundwater in various aquifers in the UAE, totaling around 675 bcm, of which fresh water constitutes no more than 25 bcm (about three percent) as shown in Figure 9.3. The estimated volume of shallow aquifers is about 470 bcm. However, Table (9-6) shows the estimates of total underground water storage by quality in the UAE.

Table 9.5
Aquifer Types, Productivity
and Quality of Water in the UAE

Aquifer Depth	Aquifer Type	Emirate/Region	Type of Water	Productivity
Shallow aquifers	Sand	Northern emirates	Fresh	Medium–High
	Natural cumulus	Northern emirates	Medium brackish	Low–High
		Abu Dhabi	Medium brackish	Medium
	<i>Sabkha</i>	Northern emirates	High brackish	Medium
		Abu Dhabi	High brackish	Medium
Alluvial	Northern emirates	Medium brackish	Medium	
	Al-Juwaiza	Northern emirates	Medium brackish	Low
	Ophiolitic	Northern emirates	Medium brackish	Low
	Cracked limestone	Northern emirates	Fresh	High
Deep Aquifers	Limestone	Abu Dhabi	Medium–High brackish	Medium
	Cracked alluvial	Fujairah	Medium brackish	Low
	Simsima	Abu Dhabi	Medium brackish	Low

Source: Ministry of Environment and Water, op. cit.; and the Environment Agency–Abu Dhabi (EAD), “Statistical Bulletin of Water Resources in the Emirate of Abu Dhabi,” Abu Dhabi, 2010.

Figure 9.3
Underground Water Storage and Quality in the UAE



Source: Ministry of Environment and Water, op. cit.

According to recent data,¹¹ and at current abstraction rates, fresh and brackish groundwater resources will be depleted in around 50 years' time. When it comes to those reserves found in shallow aquifers, this is an absolute certainty. Therefore, it is necessary to ensure that this vital resource is appropriately and sustainably managed. Nowhere is this more important than in the areas of agriculture and the 'greening' of public spaces. These two areas represent the greatest two consumers of groundwater in the UAE. Therefore, national policies to manage and develop water resources in an integrated manner must be developed in order to ensure the sustainability of these vital resources.¹²

Table 9.6**Estimates of Total Underground Water Storage and Quality in the UAE**

Water Quality	Underground Storage (BCM)							
	Abu Dhabi	Dubai	Sharjah	Ajman	Umm Al-Quwain	Ras Al-Khaimah	Fujairah	Total
Fresh <1,500 mg/l	18.5	0.03	0.53	0	0.03	0.55	0.26	20
Slightly brackish 1,500–5,000 mg/l	188	0.54	0.46	0	0.12	0.92	0.15	190
Medium brackish 5–10,000 mg/l	147	0.50	0.05	0.01	0.1	0.19	0.04	148
Slightly saline 10,000–15,000 mg/l	114	0.40	0.02	0.05	0.06	0.01	0.01	115
Saline 15,000–20,000 mg/l	56	0.05	0.04	0.01	0.03	0.01	0.01	56
Medium saline 20,000–25,000 mg/l	54	0.05	0.05	0.01	0.34	0	0.01	54
Strongly saline 25,000–40,000 mg/l	67	0.04	0.03	0.06	0.02	0.01	0	67
Brine >40,000 mg/l	90	0.4	0.03	0.02	0.4	0.01	0	90
Total	735	1.65	1.26	0.16	0.41	1.7	0.5	740

Source: Ministry of Environment and Water, op. cit.

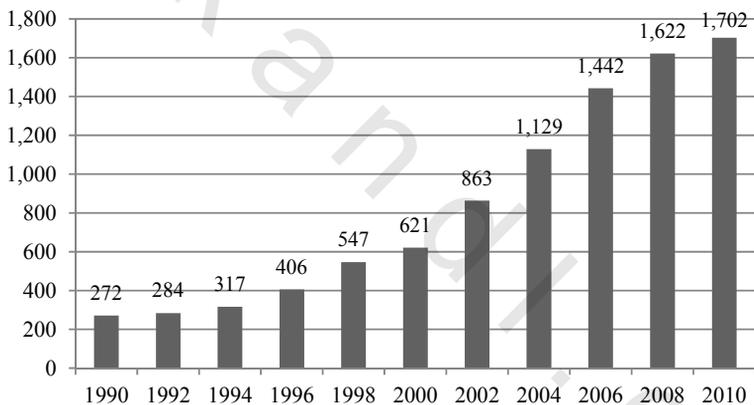
Non-conventional Water Resources

Seawater Desalination

With the deterioration of groundwater quality and the inability to meet the demand for high-quality water resources in various sectors – particularly the residential sector – the UAE government has invested in the desalination industry as a strategic option for the provision of fresh water. The desalination sector in the UAE has therefore become an important sector, significantly contributing to the development of the country.

Seawater desalination is, moreover, the primary source of fresh water in the UAE. Large desalination plants are located on the coasts of the Arabian Gulf and the Gulf of Oman. They are mostly thermal co-generation plants for the simultaneous production of electricity and water. There are some other plants located inland and operating using membrane technology (reverse osmosis). They are of low capacity and working on the production of fresh water that is often used for agricultural purposes, labor camps or industrial or oil activities in remote areas. The availability of energy, and transportation costs, are the two factors that will determine levels of desalination in the future.

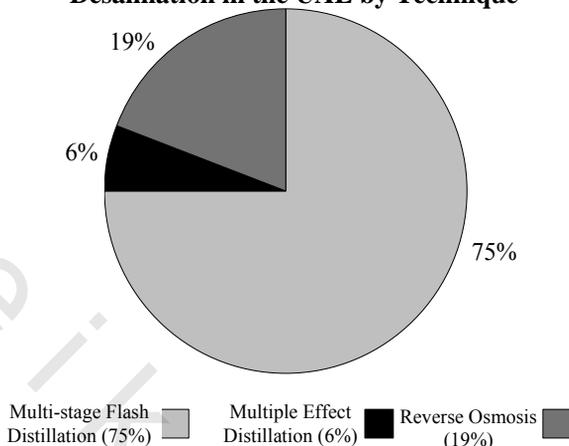
Figure 9.4
Development of Desalinated Water Production in the UAE,
1990–2010 (mcm/yr)



Source: Prepared by the researcher.

The first seawater desalination plant in Abu Dhabi began operation in 1960 – with a production capacity about 12,500 gallons per day. It was a multi-stage flash distillation (MSF) plant. The plant was shut down after a pipeline from Al-Ain city was extended to supply Abu Dhabi with groundwater. A second desalination plant was established in 1968 with a production capacity of 25,000. This was followed by three large plants with combined capacity of about two million imperial gallons per day (MIGD) in 1970.¹³

Figure 9.5
Desalination in the UAE by Technique



Source: Ministry of Environment and Water, op. cit.

Desalination capacity in the UAE has grown three-fold since 2000, due to increasing demand (Figure 9.4). The current capacity of the UAE's plants is about 1,700 mcm per year (Table 9.7), which ranks the UAE second in the world in terms of production, after Saudi Arabia. There are currently about 70 desalination plants in the UAE using thermal distillation and membranes. Thermal distillation technology includes multi-stage flash (MSF) and multiple effect distillation (MED), which are considered the most commonly used techniques due to their efficiency and the fact that they can be used in conjunction with power generation at the same plants. Use of membranes, however, is limited to the use of reverse osmosis (RO), as in Figure 9.5.

These techniques vary in terms of the volume of water needed to produce one cubic meter of desalinated water, as illustrated in Table 9.8. Water desalination using MSF is coupled with power generation to take advantage of the steam resulting from the distillation process, thereby increasing the efficiency of these plants and reducing costs. This technique is effective and reliable. Furthermore, it contributes to reducing capital costs. RO technology, in turn, is also important, as it contributes to the production of about 20 percent of the water in the UAE. It is expected that water produced using this technique will increase in the future, owing to the low cost of membranes, improved performance and low energy consumption.¹⁴

Table 9.7
Desalination in the UAE by Technique

Emirate	Plant Name	Production (1,000 m ³ /day)	Technique	Production (mcm/yr)
Abu Dhabi	Old Al-Tuwaila-A1	146	MSF	118.3
	New Al-Tuwaila-A1	240	MED	58.9
	Al-Tuwaila-A2	232	MSF	77.7
	Al-Tuwaila-B1	318	MSF	107.4
	Al-Tuwaila-B2	105	MSF	25.0
	Al-Tuwaila extension-B2	314	MSF	0
	Umm Al-Nar East-A	86	MSF	0
	Umm Al-Nar East-B	105	MSF	26.4
	Umm Al-Nar West-1-6	109	MSF	31.1
	Umm Al-Nar West-7-8	105	MSF	4.3
	Umm Al-Nar West-9-10	32	MED	0
	Umm Al-Nar West-B	286	MSF	0
	Sas Al-Nakheel	95	MSF	137.5
	Al-Mahatta	68	MSF	0
	Al-Mirfa	104	MSF	47.9
Al-Shuwaihat-1	459	MSF	150.0	
Qidfa', Fujairah	450	MSF/RO	132.5	
Dubai	Jebel Ali-D	159	MSF	58
	Jebel Ali-E	114	MSF	42
	Jebel Ali-G	286	MSF	104
	Jebel Ali-K	273	MSF	100
	Jebel Ali-L	318	MSF	116
	Jebel Ali-M	477	MSF	174
	Jebel Ali	114	RO	42
Sharjah	Al-Layyah-1	147.7	MED	82
	Al-Layyah-2	81.8	RO	0
	Al-Saj'ah	28	RO	8.9
	Kalba-1	4.8	MED	1.68
	Kalba-2	9.1	RO	5.76
	Abu Musa Island	14.8	MED	0
	Al-Zubair	0.91	RO	1.29
Ras Al-Khaimah	Sir Bu Nair	0.4	RO	0.2
	Al-Breirat	5.5	RO	2
	Al-Hamraniyah	0.7	RO	0.25
	Rafaq	0.34	RO	0.12
	Ghalilah	13.6	RO	3.56
	Al-Nakheel	72.7	MED	23.7
Ajman		70.35	MED/RO	23.58
Fujairah	Qidfa'	18.18	MSF/RO	3.09
Total				1,709

Source: Mohamed Dawoud, "Future Growth in the Desalination Industry in Middle East Region," in D. Delgado and P. Moreno, *Desalination Research Progress* (New York: Nova Science Publishers, 2008), pp. 161–186.

Table 9.8**Comparison between Desalination Techniques Used in the UAE**

Comparison	Thermal Techniques		Membrane Techniques (RO)	
	MSF	MED	Saline Water	Brackish Water
Brackish water needed to produce one cubic meter of fresh water (m ³)	10	7	2.5	1.5
Amount of high saline water (m ³)	3	2	1.5	0.5
Energy consumption (million joules/m ³)	186	162	24	29

Source: Environment Agency–Abu Dhabi, “Water Resources Management Strategy and Action Plans for the Emirate of Abu Dhabi,” Abu Dhabi, 2010.

Sources of Energy Currently Used in Desalination

Desalination plants require large amounts of energy; in the form of heat to produce steam in the case of thermal plants, while RO plants depend on electricity for the production processes. Thermal plants require temperatures of 70–130°C, and consume between 25–200 kWh per cubic meter of water. RO plants, on the other hand, require 4–6 kWh per cubic meter of water when seawater is used (depending on the salinity of water). Brackish water desalination and wastewater treatment by reverse osmosis require only about 1 kWh per cubic meter. Currently, the energy required for co-generation in Abu Dhabi is satisfied by natural gas—either from the natural gas supply network of the emirate, or from the pipelines of the Dolphin Gas Project, which imports gas from Qatar. As for the Fujairah-1 plant, it operates on natural gas supplied from Oman—the completion of the Dolphin pipelines to Oman will ensure an increase in natural gas supplies to the plant. Since 2006, shortages in the supply of natural gas to these plants led to the supplementary use of fuel and oil. It is expected that demand for energy in the desalination sector will increase in line with the growing demand for fresh water in the UAE.

Potential Future Sources of Energy for Desalination

Electricity and water production plants consume vast quantities of oil and gas. This cannot continue indefinitely, owing to diminishing reserves and high oil prices. Therefore, it has become necessary to consider the viability of sustainable alternative energy sources.

Researchers have discussed several possibilities for alternative energy sources to supply current plants. However, alternatives bring their own problems. For example, the use of coal to power desalination plants would lead to extensive pollution—although Abu Dhabi has high atmospheric pressure, so the spread of contaminants is limited. Of course, renewable energy provides an alternative that is much less destructive to the environment. The UAE has taken two major steps in the use of solar and nuclear energy.

- Solar energy:the Abu Dhabi government has established the Abu Dhabi Future Energy Company (ADFEC, also known as “Masdar”) with the main objective of investing in renewable energy alternatives that can be used in power generation and water desalination. The two renewable energy sources available in Abu Dhabi are solar and wind power. Solar energy potential in the Gulf region can exceed 1 kilowatt per square meter, and is available almost all year round.

Researchers outside Masdar have studied the use of solar energy in desalination; however, the current technology does not provide the capacity or the safety required in Abu Dhabi’s case. The results of recent steps towards the use of large fields for solar energy generation in the UAE, as well as global developments in this field, should be monitored carefully. The emirate of Abu Dhabi has initiated a pilot project that aims to create around 30 small solar desalination units with a production capacity of five cubic meters per unit per hour, with the aim of developing this system in remote areas of Abu Dhabi where there is no other source of water.¹⁵

The use of solar energy for desalination has many advantages: it has less of an impact on the environment and global warming due to the absence of emissions; operating costs are lower than other methods; the returns on capital costs are better in the long term than other sources;

and capital costs will fall over time due to the development of the solar cell industry, in addition to the possibility of using solar collection mirrors which will greatly increase the efficiency of such systems.

Among the current challenges facing solar desalination is the high (current) capital cost compared with traditional methods. However, there are better prospects for long-term cost recovery when compared to traditional energy types. The second challenge is land use; but the development of the solar cell industry is gradually reducing the area of land required. Also, while the current efficiency of solar cells does not exceed 18 percent, studies indicate that some companies have developed cells with an efficiency of up to 33 percent (which are expected to enter the market soon). The third challenge is the need to store energy for use at night—a very costly element in the establishment of such plants.

- Nuclear energy: the UAE took a clear decision to evaluate the possibility of developing nuclear energy in its “Policy of the United Arab Emirates on the Evaluation and Potential Development of Peaceful Nuclear Energy,” published in April 2008. This strategy envisages semi-reliance on nuclear energy starting in 2017. This will require strict policy decisions to protect the environment. Nuclear energy may represent the best economic alternative to fossil fuels in electricity generation and desalination. However, the use of nuclear energy – especially following the Fukushima disaster in 2011 – raises some safety concerns among researchers and the public. Other questions are raised concerning the high capital and operating costs of such plants; the potential radioactive impact on workers and the areas surrounding such plants; and arrangements for the disposal of nuclear wastes. Nevertheless, these concerns should not lead to the option being overlooked, as it might be the only option available.

Reports released by the International Atomic Energy Agency (IAEA) have shown that the use of nuclear energy in desalination is less expensive than that conventional fuels. Furthermore, the success of linking desalination units with nuclear energy plants has been demonstrated—it was first used in Kazakhstan (the former Soviet Union), where a nuclear energy plant was used for 27 years for the production of electricity (135 MW) and desalination (with a capacity

of 80,000 m³ per day). There are also many other countries that have recently begun using nuclear energy in desalination.¹⁶ In Japan, 10 desalination plants were linked to nuclear power plants using pressurized light water reactors, each with a capacity of 1,000–3,000 m³ per day. In this example, MSF units were initially used, which were later replaced with RO and MED units.

In India, two pressurized heavy water nuclear plants were built with a capacity of 170 MW_e each. They were linked to a pilot RO desalination plant with a capacity of 1,800 m³ per day, and to a MSF plant with a capacity of 4,500 m³ per day.

Similar projects are in their early stages in the Middle East; for example, Iran has designed a desalination plant with a capacity of 200,000 m³ per day to be linked to the Bushehr reactor; Libya signed an agreement with France to build a nuclear desalination plant; and Qatar is seriously considering the construction of a nuclear power plant linked to a desalination plant with capacity of 1.3 mcm per day. Table 9.9 details selected projects linking desalination plants to nuclear power plants, as well as the desalination techniques used.

Table 9.9
Present and Proposed Nuclear Desalination Plants

Type of Reactor	Country	Desalination Technique	Status
Liquid metal fast reactor	Kazakhstan	MED, MSF	completed
Pressurized light-water reactor	Japan	MED, MSF, RO	completed
	Korea, Argentina	MED, RO	design phase
	Russia	MED, RO	design phase
Pressurized heavy-water reactor	India	MSF, RO	Delivery phase
	Canada	RO	design phase
	Pakistan	MED	under construction
Boiling light-water reactor	Japan	MSF	completed
Very high temperature reactor	South Africa	MED, MSF, RO	design phase
	China	MED	design phase

Source: Mohamed Darwish, Fatimah M. Al-Awadhi and Anwar O. Bin Amer, "Electricity Generation and Seawater Desalination Using Nuclear Energy in the State of Kuwait and the Gulf Countries" (Kuwait Foundation for the Advancement of Sciences, 2009).

Environmental Impacts of Desalination Plants

Like any other industry, desalination has some negative effects on the environment. Therefore, necessary precautions must be taken to mitigate these effects. Desalination plants contribute to global warming via their heavy consumption of fossil fuels, and resultant emissions. At present there is no accurate data concerning the amount of greenhouse gases (GHGs) associated with desalination in the UAE. The Abu Dhabi Water and Electricity Authority (ADWEA) estimated in 2006 that the total volume of GHGs emitted by desalination and power generation plants in the emirate of Abu Dhabi was about 13.5 million tons per year—of which approximately 99.5 percent was carbon dioxide. The government has made great efforts in order to make these emissions conform to international standards by increasing the efficiency of desalination plants and the use of natural gas to fuel such plants.¹⁷ Moreover, the discharge of highly saline water into surrounding waters leads to negative physical, chemical and biological effects on the bio-marine environment.

Economic Aspects of Desalination

Desalination is expensive in terms of capital, operating and maintenance costs, as well as indirect costs such as the harmful impact on the environment, the consequences of the greenhouse effect, and the impact on marine organisms.

Table 9.10**Capital Costs and Energy Required to Produce One Cubic Meter of Desalinated Water**

Element	Desalination Technique		
	RO	MED	MSF
Operating temperature (° C)	< 45	<70	<120
Average energy consumption (kWh /m ³)	6	11	21
The cost of energy to produce a cubic meter (\$/m ³)	0.57	1.04	1.97
Capital cost (\$/m ³)	750	850	900

Source: Darwish, Al-Awadhi and Bin Amer, "Electricity Generation and Seawater Desalination Using Nuclear Energy in the State of Kuwait and the Gulf Countries," op. cit.

Desalination costs are affected by many factors, including: the type of technique used; the production capacity of the plant; the nature of the water supply to the plant (temperature and salinity); geographic location; availability of raw materials; labor costs, etc. Moreover, the cost of the fuel used to operate these stations is one of the most important operational costs, as illustrated in Table 9.10. The table indicates that the cost of producing one cubic meter of desalinated water in the UAE is approximately AED 7.

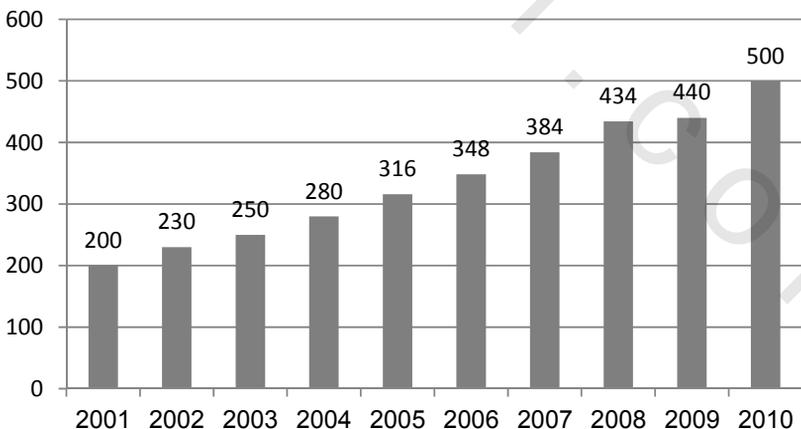
Treated Wastewater

Treated wastewater is a valuable and important resource in countries suffering from water scarcity—especially now that modern treatment systems are capable of producing safe drinking water in accordance with World Health Organization (WHO) criteria. This water can therefore be used directly or to recharge aquifers.

The UAE government has therefore exerted substantial effort in developing the treatment and reuse of wastewater. Since 1973, wastewater collected from a network of cities and residential areas in the UAE has been treated, and over this time the capacity of wastewater treatment plants in the UAE has greatly developed, as shown in Figure 9.6.

Figure 9.6

Treated Wastewater Production in the UAE (mcm), 2001–2010



Source: Ministry of Environment and Water, op. cit.

Today there are more than 60 treatment plants of various sizes in the UAE—32 stations in Abu Dhabi, 4 in Dubai, and 18 in the emirate of Sharjah, with the remainder distributed among the other emirates. Wastewater is collected from a network comprising about 10,000 kilometers of sewers. The total amount of treated wastewater in the state reached about 500 mcm/yr in 2010. Production of treated wastewater is expected to increase to reach 1,200 mcm by 2030—providing that the population continues to increase at the current rate. Table 9.11 shows projected treated wastewater production in the UAE (2010–2030) based on the assumptions that residential and government sectors will represent the main source of wastewater, that industrial wastewater will be treated within the industrial zone of production, and that the average per capita production of wastewater will be 200 liters per capita per day.

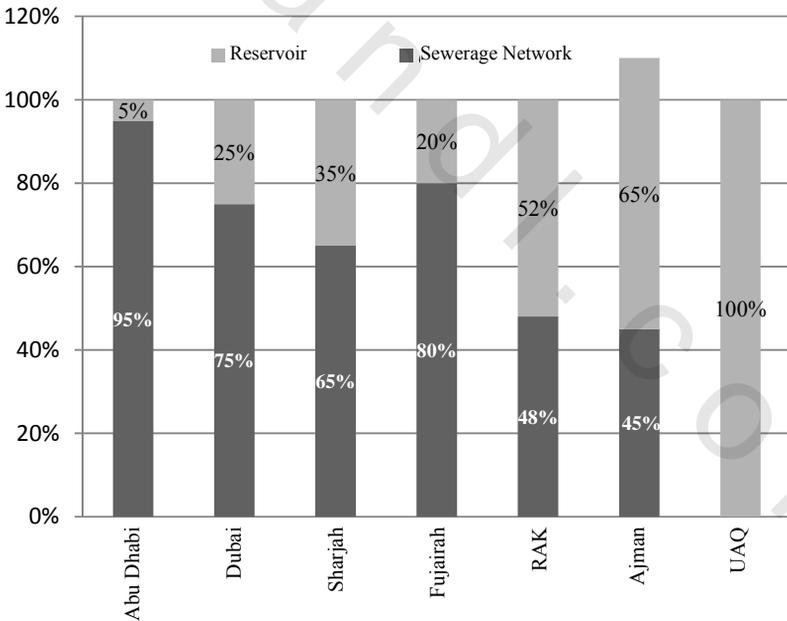
Table 9.11
Projected Production of Treated Wastewater in the UAE (mcm)

Emirate	Indicator	2010	2015	2020	2025	2030
Abu Dhabi	Population	1,664,950	1,996,595	2,394,328	2,871,293	3,443,271
	Quantity of wastewater	119	143	171	205	246
Dubai	Population	1,847,925	2,681,438	3,890,908	5,645,915	8,192,522
	Quantity of wastewater	132	191	277	403	584
Sharjah	Population	1,093,567	1,564,852	2,239,242	3,204,269	4,585,185
	Quantity of wastewater	78	112	160	228	327
Ajman	Population	264,229	347,963	458,233	603,447	794,675
	Quantity of wastewater	19	25	33	43	57
Fujairah	Population	160,350	208,340	270,755	351,850	457,256
	Quantity of wastewater	11	15	19	25	33
Ras Al-Khaimah	Population	248,067	298,488	359,210	320,210	520,125
	Quantity of wastewater	18	21	26	31	37
Umm Al-Quwain	Population	58,460	71,166	86,584	105,530	128,165
	Quantity of wastewater	4	5	6	8	9
UAE	Population	5,440,744	7,516,186	10,412,112	14,462,088	20,138,280
	Quantity of wastewater	503	625	779	973	1,218

Source: Ministry of Environment and Water, op. cit.

The UAE has achieved great progress in recent years in developing its wastewater collection and treatment system—by extending sewer networks and building assembly reservoirs. In some areas, assembly reservoirs are used (as shown in Figure 9.7). Advanced systems are used up to the third (tertiary) stage of treatment, which allows the reuse of water resulting from the treatment process on a wide scale, especially in landscape irrigation. The UAE constructed its first treatment plant (activated sludge) in 1973 to serve 30,000 inhabitants in Abu Dhabi, with an approximate capacity of 6,810 m³ per day. Today, the total number of wastewater treatment plants exceeds 40, producing about 500 mcm of treated water. Total production is expected to eventually exceed 1.2 bcm per year.

Figure 9.7
Sewerage Network Services Coverage in the UAE



Source: Prepared by the researcher.

Most plants in the UAE use advanced treatment techniques, resulting in a high quality water.¹⁸ Most of this water – up to 60 per cent of the total treated wastewater – is used to irrigate gardens, parks and some plantations or recreational areas. The rest is discharged into the Arabian Gulf or the desert. However, plans are being made to maximize the benefits of using this water, ensuring 100 percent utilization in the following areas:

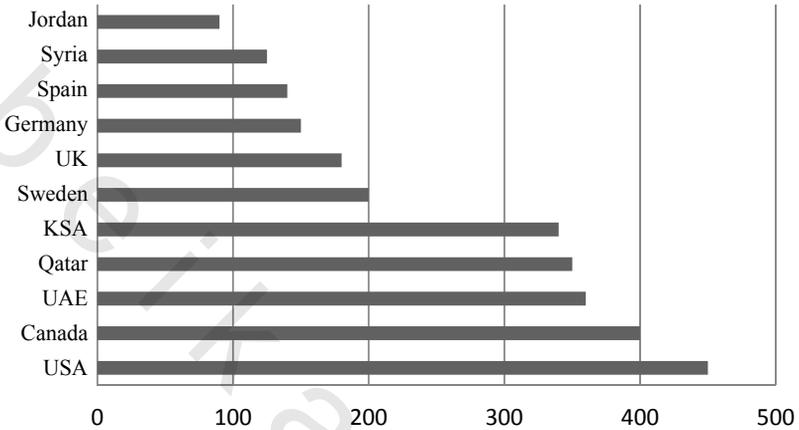
- Beautification: irrigating landscaped areas alongside main roads.
- Agriculture: to support food security—after making sure of the suitability and quality of water produced and its conformity with local and international standards.
- Central cooling: replacing large quantities of high-cost desalinated water currently used in the central cooling process.
- Recharging aquifers by exploiting the ability of the soil to further purify and treat water; then pumping this water and reusing it.¹⁹ There is currently a project which aims to inject treated wastewater into Dubai’s aquifer—this water would then be reused in irrigation.

Water Demand in the UAE

The average per capita daily consumption of water in the UAE is one of the highest in the world, as shown in Figure 9.8.²⁰ The UAE is the second largest producer of desalinated water globally, following Saudi Arabia. It uses most of its desalinated water to meet the demand for drinking water or urban consumption for domestic and industrial purposes. Part of it is also used to irrigate gardens in urban areas, agricultural areas as in Al Ain and some farms on the Dubai–Abu Dhabi border. Meanwhile, groundwater is used for agricultural irrigation, and reclaimed water is used in gardens and parks.

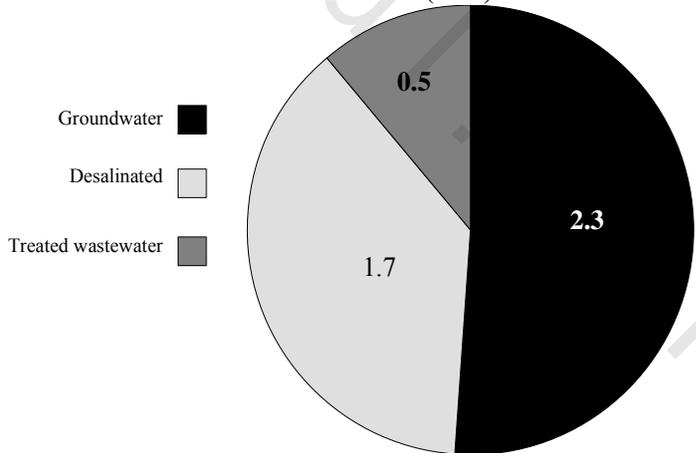
Total annual water consumption in the country is about 4.5 bcm, of which natural renewable and non-renewable (mainly groundwater) resources account for about 2.3 bcm or about 51 percent, comprising 150 mcm of renewable groundwater from both dams or rain runoff. Total non-natural renewable resources comprise 2.2 bcm, of which 1.7 bcm or 37 percent is desalinated water, and about 500 mcm or 12 percent is recycled sewage water (Figure 9.9).

Figure 9.8
Average Daily Per Capita Consumption of Water
in the UAE vs. Other Countries (liters per capita per day)



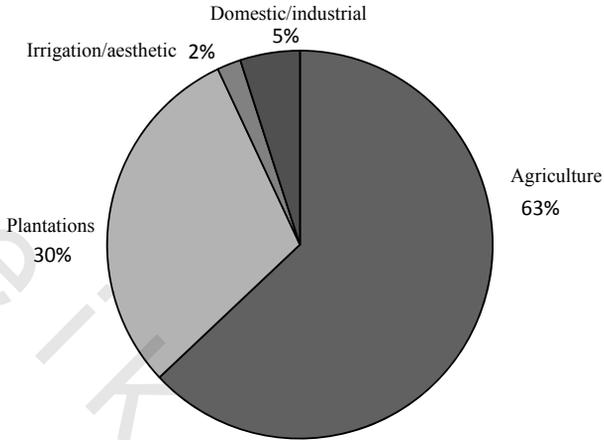
Source: Prepared by the researcher based on various sources.

Figure 9.9
Water Resources in the UAE (bcm)



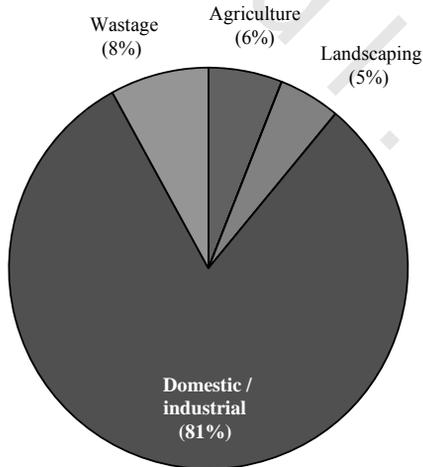
Source: Ministry of Environment and Water.

Figure 9.10
Usage of Groundwater by Sector



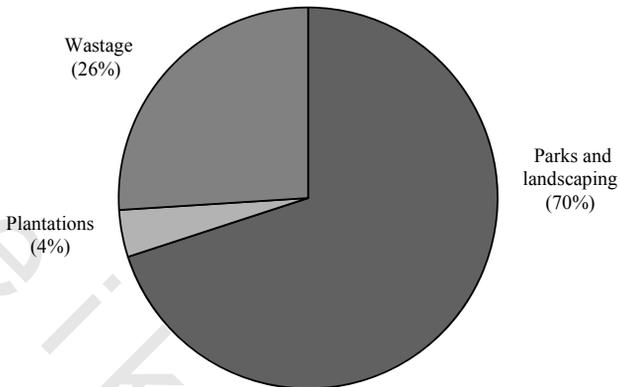
Source: Ministry of Environment and Water, op. cit.

Figure 9.11
Use of Desalinated Water by Sector



Source: Ministry of Environment and Water, op. cit.

Figure 9.12
Use of Reclaimed Wastewater per Sector in Abu Dhabi



Source: Ministry of Environment and Water, op. cit.

Groundwater

Most groundwater is used for irrigation purposes, whether in the agricultural or plantation sectors or for civil horticulture. The agricultural sector consumes about 1.5 bcm (equivalent to 63 percent of total groundwater usage in the country). The plantation sector consumes about 690 mcm, (equivalent to 30 percent), while about 120 mcm (5 percent) of fresh and desalinated groundwater is used in domestic and industrial purposes, and about 50 mcm (two percent) for the irrigation of landscaping activities in urban areas, as shown in Figure 9.10.

Desalinated Water

Most desalinated water is used for drinking and domestic use, as well as in the industrial and commercial sectors. The total production of desalinated water is about 1.7 bcm, of which around 1.35 bcm is used in urban areas for domestic, industrial and commercial uses – including irrigation of home gardens – while about 90 mcm is used for agricultural purposes on farms, and 80 mcm for ornamental horticulture, gardens and parks. About 180 mcm is lost (leaked) though

the distribution network (five percent) and distribution sub-network (18–20 percent). Figure 9.11 demonstrates the usage of desalinated water by sector.

Reclaimed Wastewater

Reclaimed wastewater production totals about 500 mcm, of which about 60 percent is used for decoration, gardens and parks. The Abu Dhabi government is currently conducting a study to reduce the amount of water being pumped into the environment, estimated at 350 thousand cubic meters per day, so that 100 percent of the reclaimed wastewater is utilized by the end of 2012. Figure 9.12 shows illustrates the use of reclaimed wastewater in Abu Dhabi.

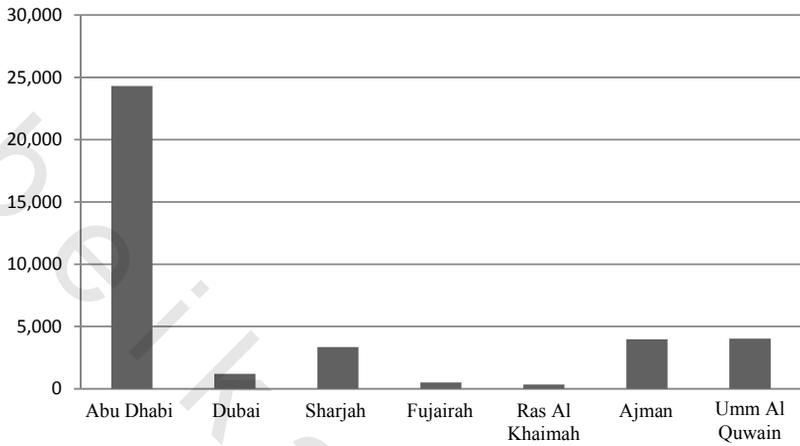
Water Consumption by Sector

Agriculture

Irrigation is the largest source of water consumption in the UAE. It can be divided into three main areas: agriculture; plantations; and gardens, parks and roadside green belts. Currently the bulk of the demand for irrigation for agriculture and plantations is met by groundwater supplies, while the needs of gardens and parks are met through reclaimed wastewater, desalinated water, and occasionally groundwater.

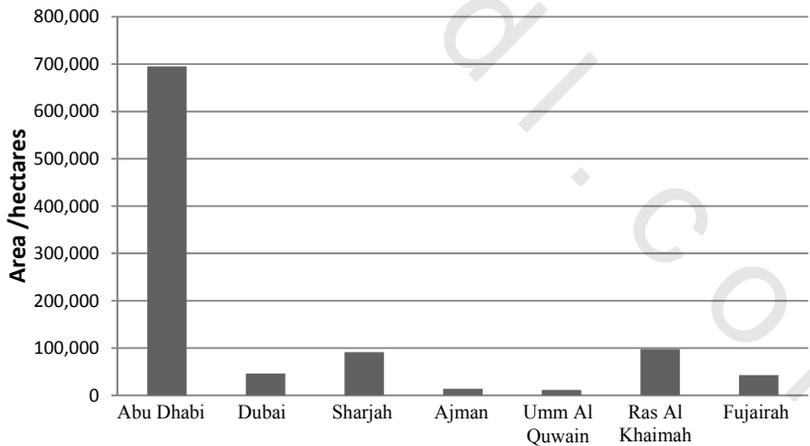
The process of distributing water for irrigation purposes is expected to witness a change in terms of its sources and priorities as a result of the increasing demand from the non-agricultural sector, the growing population, and ongoing urban and industrial development. There is already an increase in the demand for water as a result of the expansion of the agricultural sector and the growing number of parks, gardens and artificial landscaping activities. The main objectives of agricultural irrigation are: food production and increasing self-sufficiency; the elimination of poverty; improving environmental conditions and systems; and protecting the environment and its natural resources.

Figure 9.13
Number of Farms by Emirate



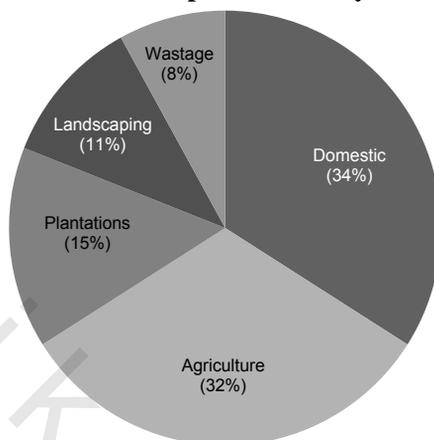
Source: Prepared by the researcher.

Figure 9.14
Farmed Area in the UAE by Emirate



Source: Ministry of Environment and Water, op. cit.

Figure 9.15
Water Consumption Rates by Sector



Source: Ministry of Environment and Water, op. cit.

The culture and heritage of the UAE are linked to its land and water. The country has a long tradition of agriculture in the oases, where some crops have been grown for 5,000 years. Following the establishment of the UAE in 1971, the government sought to support small traditional farms and extend them by thousands of hectares using groundwater. As a result the number of farms in the country has reached 37,710, spread over the different emirates, in Abu Dhabi alone there are around 24,300 farms, as shown in Figure 9.13, with a total cultivated area of around 800 hectares, as shown in Figure 9.14, according to 2010 statistics.

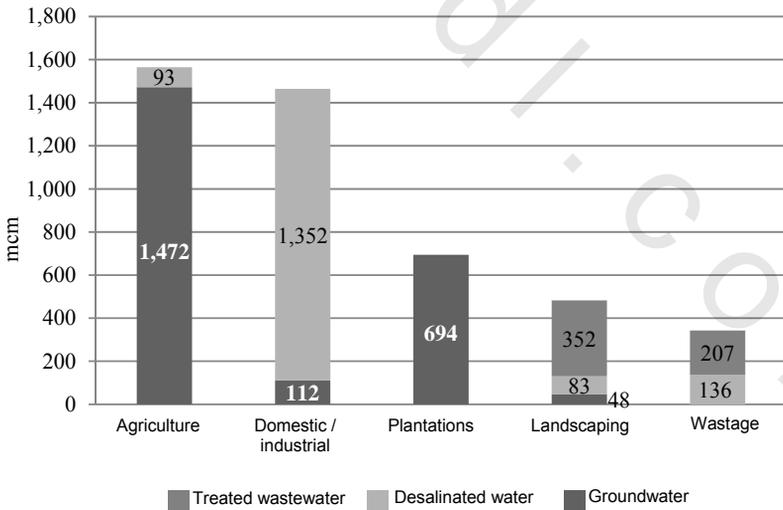
The agricultural sector is the largest consumer of water in the country, accounting for 1.56 bcm or 34 percent of total water resources. About 95 percent of its needs are met by groundwater, as shown in Figure 9.15. The quantity of desalinated water used in the agricultural sector is about 90 mcm per year. In an initiative launched by the UAE government to rationalize water use in the agricultural sector and increase efficiency, an agricultural policy has been developed by which the cultivation of Rhodes grass (*Chloris gayana*) has been limited after it was determined to be the crop with the highest water consumption. Modern equipment and technologies have also been introduced to the sector such as greenhouses and modern

irrigation methods. Studies indicate the possibility of maximizing the use of irrigation water, whereby 80 kilograms of tomatoes can be produced per cubic meter of water, compared to six kilograms using traditional methods.

Plantations

There are about 300 plantations in the UAE comprising bushes, shrubs and small trees, with a total area of 210,000 hectares (ha). These plantations consume about 694 mcm of water per year, 15 percent of the total water resources of the country, and mostly in the form of saline groundwater. There has been a decline of up to 40 percent in water consumption of the plantation sector since 2003 due to a reduction in the area of these plantations—such as *U Aldebssa* in the Western Region of Abu Dhabi. However, on the eastern side of the emirate the plantations’ demand for water has increased by 1.5 percent, and the government has sought to increase their area, enhancing efficiency and improve irrigation methods.

Figure 9.16
Water Resource use by Sector and Source



Source: Ministry of Environment and Water, op. cit.

Ornamental Plants and Gardens

The UAE government has focused on improving the living conditions of individuals. To that end, it has expanded ornamental horticulture, public gardens and parks, and recreational facilities such as golf courses and sports arenas. There are currently over 100 gardens and parks in the country, as well as numerous entertainment venues and road side plantations, which also fall under this sector. This sector consumes about 490 mcm of water, most of which comprises reclaimed wastewater.

In order to rationalize water consumption in this sector, the government has adopted a policy to reduce green spaces, while also employing modern irrigation systems. This may reduce water consumption significantly—by up to 60 percent.

Domestic, Industrial and Commercial Sector

There has been a major construction boom in the United Arab Emirates over the past forty years, accompanied by a significant increase in population. The domestic, industrial and commercial sector consumes some 1.4 bcm of water annually, or 34 percent of the total water resources of the nation. Desalinated water provides 1.26 bcm (90 percent) while the remainder is met by groundwater. In light of the country's commitment to support the supply of freshwater resources, water consumption has increased gradually and steadily alongside the increase in population, urban growth and industrial expansion.

Estimated water consumption in urban areas (including domestic and industrial, commercial and government facilities) is about 750 liters per person per day, which is one of the highest rates in the world. Estimated water consumption in the domestic sector alone is about 364 liters per person per day. Studies conducted by the Regulation and Supervision Bureau (RSB) and the Environment Agency – Abu Dhabi (EAD), have shown that daily per capita consumption of water varies depending on the standard of living and the emirate, ranging from 200 liters per capita per day in Sharjah to more than 550 liters in Abu Dhabi, with an average of 360 liters per capita per day at the state level. Figure 9.16 shows total water resource use in the country.

Future Demand for Water Resources

The process of calculating future demand for water is complex and multi-dimensional. There are many factors that must be taken into account when making such calculations, which sometimes requires the use of complex mathematical models and the development of various scenarios and assumptions. There are also sector-specific factors that affect future demand.

The most important factors in the domestic sector are: projected rate of population growth; per capita consumption of water (liter per capita per day); the impact of outreach programs and rationalization to change patterns of per capita consumption; effectiveness of water policies and pricing; urban growth; availability of transmission and distribution networks; and personal income level.

Factors affecting the agricultural and plantation sectors are: potential expansion of cultivated areas; crops and types of plants, and their associated water needs; current and future methods of irrigation; effective sector-specific water policies; weather conditions (temperature, humidity, wind, evaporation and other factors); government approaches to rationalizing the use of aquifers and the availability of alternative water sources.

Domestic Water Demand Growth

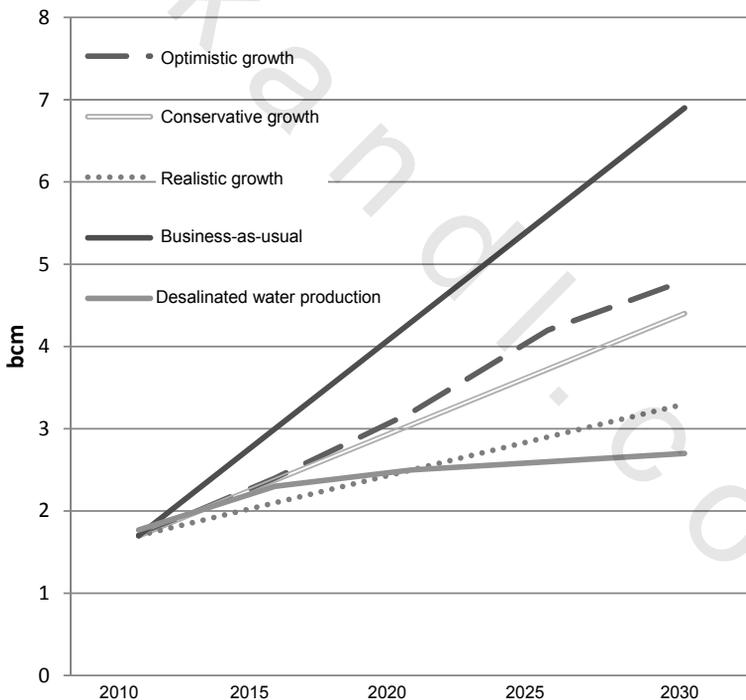
To calculate projected growth in domestic demand for desalinated water, the Ministry of Environment and Water, in cooperation with other national stakeholders, devised the following scenarios:

- **Optimistic growth:** this assumes a domestic sector growth rate of ten percent until 2020, and a rate of 1.5 percent thereafter. This scenario assumes demand growth in the commercial and industrial sectors of thirteen percent annually until 2015, ten percent until year 2020, and 6.9 percent until 2030.
- **Conservative growth:** this assumes a population growth rate of eight percent until 2020, and then 1.5 percent thereafter until year 2030. Annual demand growth in the commercial and industrial sectors is estimated at thirteen percent until 2015, then eight percent until 2020, and 6.9 percent until 2030.

- Realistic growth: this assumes a population growth rate of nine percent until 2015, then 3.5 percent until 2020, and 2.5 percent thereafter until 2030. Demand growth in the commercial and industrial sectors is estimated at nine percent per annum to 2015, and three percent to 2030.
- Business-as-usual: this scenario assumes current growth rates remain as they are until 2030, when the country's population is expected to reach 20 million people.

Figure 9.17

Projections of Domestic Demand for Desalinated Water



Source: Ministry of Environment and Water, op. cit.

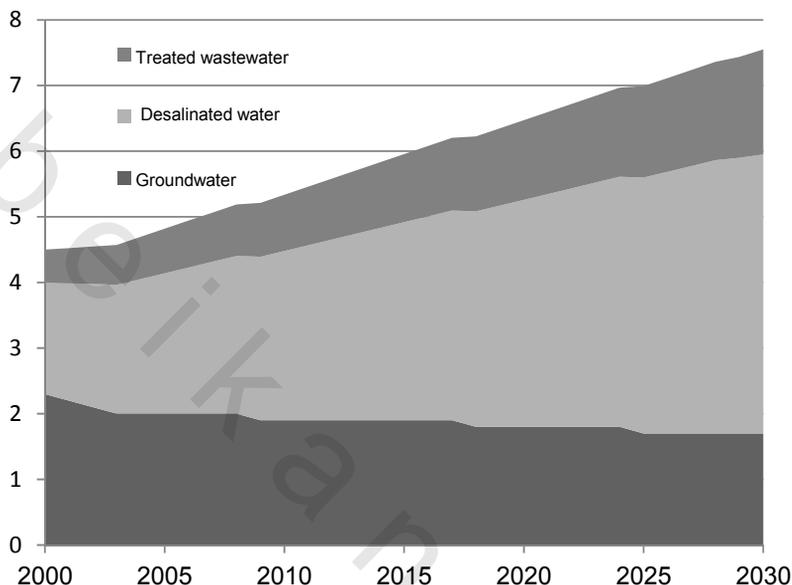
A numerical model has been used to represent the domestic sector demand in the period 2010–2030. Figure 9.17 shows the results of the calculations, which indicate that demand from the domestic sector will reach 4.8 bcm per annum according to the optimistic growth scenario; 4.4 bcm in the conservative projection; 3.3 bcm in the realistic projection; and 6.9 bcm in the business-as-usual projection. The results indicate that there will be a gap between water demand and available resources in the absence of the following:

- Demand management in the domestic sector to rationalize consumption through the use of water-saving tools and the application of modern standards and specifications in the distribution and transmission networks, reducing wastage caused by network leakage.
- Government measures to establish laws and legislation to reduce water wastage, including by the use of incentives.
- Changes in water pricing policies by the establishment of varying water tariffs according to consumption (varied tariff system).
- Reduction in the amount of desalinated water used in agriculture, and substitution by other sources such as reclaimed wastewater or a mixture including groundwater.
- Investment to build new desalination plants or increase the production capacity of existing plants.

Demand Growth in the Agricultural Sector

Cultivated land in the UAE has increased significantly during the period 1971–2011. Crops differ from emirate to emirate, with vegetables grown in the Northern emirates, fodder and palm trees in Abu Dhabi, and fruit in the eastern region. The agricultural sector accounts for about 90 percent of the groundwater consumed in the UAE, as well as about 20 percent of desalinated water. It is expected that the demand for water from this sector will rise from 4.5 bcm in 2010 to more than 7.5 bcm by 2030 (Figure 9.18).

Figure 9.18
Projected Demand to 2030 (bcm)



Source: Ministry of environment and water, op. cit.

A Legislative and Institutional Framework for the Management of UAE Water Resources

The UAE has devoted much effort to the organization of the water sector and has developed legal, legislative, regulatory and institutional frameworks to support the implementation of appropriate policies and administrative decisions with which to efficiently manage this vital resource. Through these efforts, undertaken over forty years, steps have been taken to identify a competent authority, as well as the roles and responsibilities of various institutions in the country. A framework has also been developed through which management concepts and sustainable development of water resources can be developed and integrated.

Regulation of Groundwater Usage

At the federal level, the Ministry of Environment and Water has played a key role in maintaining groundwater resources and in developing public policies, national standards, and a strategic plan for groundwater, coordinating these activities among the different Emirates. Then comes the role of local authorities in the implementation of controls and legislation regulating groundwater uses, granting permits for well-drilling and other activities.

There has been extensive depletion of groundwater reserves due to increasing demand from the 1960s onwards, the revival of the agricultural sector, plantation projects and landscaping, the creation of parks and gardens, and a deterioration in the quality of groundwater aquifers. The UAE has therefore established standards and legislative frameworks to organize the process of well-drilling, and each emirate has issued a law regulating this process. Most of these laws are similar in terms of content, and all aim to achieve a number of objectives, namely: identification of those responsible for organizing well-drilling and the granting of drilling licenses; reduction of overdraw and indiscriminate drilling; preserving groundwater quantity and quality; determining uses of, and control measures for groundwater.

Regulation of Desalinated Water Usage

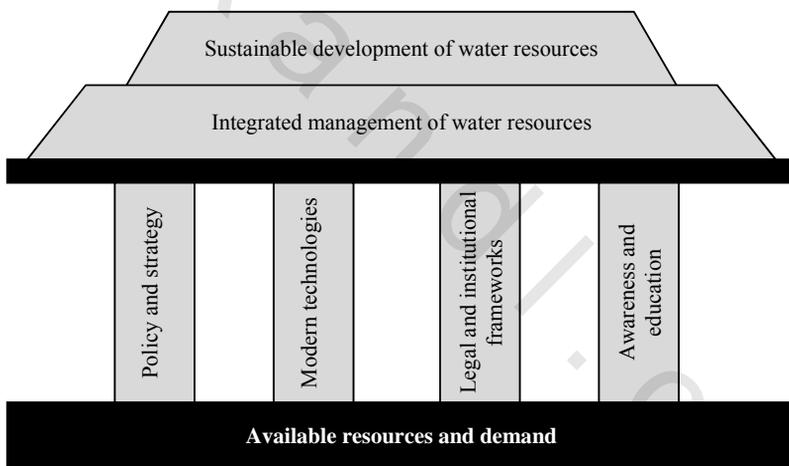
At the federal level, the Ministry of Energy is responsible for desalination policy and strategic planning, as well as the development of national standards in this area and the coordination of activities between the different emirates.

There is no separate federal law governing desalinated water, but it is addressed in general in Federal Law No. (24) of 1999, which sets standards for pumping and discharge of water to and from the sea. Also, Decree No. (37) of 2009 concerning the establishment of a supreme council for electricity and water chaired by the Minister of Energy, tasks the council with the coordination of desalinated water production activities—an important step in coordinating roles among the bodies responsible for the production, distribution, control and regulation of desalinated water.

Regulation of Wastewater Treatment and Usage

The General Secretariat of UAE Municipalities was responsible for sewage follow-up and treatment until 2009, when the Ministry of Environment and Water assumed responsibility. Federal Law No. (24) of 1999 contains three articles concerned with wastewater treatment and usage: Articles 35, 37 and 38. The regulatory and legislative frameworks also cover the reuse of wastewater in Abu Dhabi, which issued Law No. (21) of 2008 allowing Abu Dhabi Sewerage Services to sell reclaimed wastewater to developers and the private sector whereas previously reclaimed water could only be sold to the municipalities.

Figure 9.19
Work Plan for Integrated Water Management in the UAE



Source: prepared by the researcher.

Towards Integrated Management and Sustainable Development of Water Resources in the UAE

In order to achieve integrated management and sustainable development of scarce water resources in the UAE, the government is undertaking a

variety of measures in the following four main areas in order to achieve water security:

- Developing public policy that reflects the government's vision to achieve sustainable development of water resources, as well as a strategic plan for specific goals and standards to measure performance levels. This will be followed by a schedule of programs and projects to achieve the desired objectives. To ensure success, there is a follow-up and evaluation process comprising performance indicators and tools.
- Reviewing legislative and legal frameworks, as well as the institutional and regulatory framework for the management of water resources in the state, in order to identify any omissions or inconsistencies in terms of reference, and to develop the necessary programs to avoid such inconsistencies.
- Raising awareness and education through the development of educational programs for all water-consuming sectors. These programs are designed based on the 'message' to be delivered, as well as on the specific target groups, their scientific and cultural background, and language.
- Developing and adopting modern technologies in order to rationalize water usage in all water-consuming sectors, as well as raising the efficiency of water production and reducing its cost.